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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Contents

Executive summary

The ICES Study Group on Risk Assessment and Management Advice (SGRAMA) met at the ICCAT Headquarters, Madrid, Spain, 23–27 November 2009. This was the fourth and final meeting of the Study Group.

Through a variety of work (including ICES expert groups and EU and nationally funded research projects) competence has been developed on risk-based management within the ICES area. Considerable experience has been gained in research studies adapting best practice risk assessment methodologies for use within ICES fisheries. This competence and experience provides the basis for moving risk based management to an operational status within ICES. Further research should, of course, be ongoing. However, the decision to move to risk analysis as an operational management tool within ICES should now be considered a strategic policy decision, not a scientific one. The specific challenges in implementing such management within ICES, which are not relevant at a national level, are those associated with the multinational nature of ICES fisheries management. Lessons can be drawn from other disciplines where transnational directives related to the environment have been successfully implemented within ICES and the European Union.

During the lifetime of SGRAMA we have been fortunate to have had the benefit of experts from Australia, South Africa and Canada presenting the details of existing best practice risk-based fisheries management. In addition experts from RFMOs and disciplines other than fisheries have contributed expertise and experience. Brief overviews, and links to relevant literature, have been presented for South Africa (ICES, 2007), Canada (ICES, 2008), and Australia (Section 7). In all cases the approaches involve a structured and transparent risk assessment system, and the adoption of an iterative approach where experience gained is used to improve the process based on experience gained.

The SGRAMA group has produced an overview of critical issues relating to risk in fisheries management (Section 3). An overview of previous reports is presented in Section 5, outlining the areas that have been covered during the lifetime of the Study Group on Risk Assessment and Management Advice. A high level overview of some related work within ICES and several EU and nationally funded projects (such as PRONE, JAKFISH and DEFINEIT) was presented which mapped out the expertise and competence that has been developed and would be available to support the use of risk assessment as an operational tool for ecosystem management in ICES fisheries. Finally an outline of three risk assessment frameworks currently in use in Australia has been given in Section 7. Several documents in Annex 2 give more detail on some of the work described in this report.

It is hoped that this document, together with previous reports, provides an overview of risk analysis in fisheries management around the world, and highlights how such approaches would be both valuable and feasible within ICES.

1 Opening of the meeting

The meeting opened at 10:00 on 23 November 2009. The Chair was unable to attend the meeting, as a result of illness. The first order of business was therefore to elect an interim Chair for the meeting; Dr Daniel Howell from IMR Bergen was selected. The list of participants and contact details are given in Annex 1. The venue was the ICCAT headquarter in Madrid. The meeting facilities are well suited for such a meeting, and we are grateful to ICCAT for their cooperation in hosting the meeting.

2 Adoption of the agenda

The terms of reference for this meeting were as follows:

a) on the basis of the previous SGRAMA meetings and reports, input from WGFS and experience gained elsewhere, continue to develop operational guidelines for risk assessment as a part of the fisheries management advice process by:

   i) identifying potentials for measuring or estimating consequences and probabilities;

   ii) relating indicators to negative consequences and developing management procedures based upon such indicators;

   iii) considering different approaches to risk identification;

   iv) considering risk communication as a part of traditional fisheries management advice;

   v) and in further detail suggest what elements or phases of a risk assessment is best suited for expert groups only.

b) present previous reports and proposed guidelines and framework to scientists outside SGRAMA and incorporate comments and suggestions;

This report focuses on ToR a), providing operational guidelines for incorporating risk analysis into management of ICES fisheries. ToR a(i) is covered in Section 3, 6.1 and Section 7; ToR a(ii) is covered in 6.5, 6.6 and Annex 2; ToR a(iii) in 3, 6.1, 6.3, 7 and Annex 2; ToR a(iv) in Section 3, 6.1, 6.4 and 7; and ToR a(v) in Section 3. The report provides a basis for communicating these issues outside SGRAMA, as required in ToR b. The report has been structured to provide an overall outline of the critical points in adopting a risk assessment based approach to fisheries management, and a review of a number of projects within ICES and the EU where competence and tools are being developed that could be utilized in moving towards making risk-based management operational within ICES.

3 Applying Risk Analysis in Fisheries

Risk analysis is an established strategy in disciplines where uncertainty is present and consequences vary. Risk analysis can be used to prioritize the use of limited resources or develop strategies that are robust to the various types of uncertainty. It is therefore un-surprising that risk analysis is already comprehensively used to support ecosystem approach to fisheries in many jurisdictions. [1]

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[1] Ecosystem-based fisheries management is a strategy to implement an ecosystem approach to fisheries.

The ecosystem approach to fisheries (EAF) involves planning, developing, and managing fisheries in a manner that address the multiple needs and desires of society without compromising the options for future generations (FAO 2005a). EAF is consistent with EU fisheries policies that require the integration of international, national and local environmental issues. The ecosystem approach to fisheries is also the underlying approach within Norwegian and Australian fisheries management policies. Implementation of the EAF requires consideration of a broader range of issues and options than conventional single species fisheries management.

If management advice for ICES fisheries aims to integrate the principles of EAF then decisions need to be taken about the scope and implementation of risk-based methods. Various approaches are already available, including those developed by ICES Working Groups and national and EU projects, to move this strategy forward. This report outlines these approaches and summarizes other relevant research. Implementation of relevant, effective and efficient risk-based approaches will improve outcomes across the mosaic of ecological, economic and social issues that constitute contemporary fisheries.

The following statements summarize the arguments presented in this report:

- Risk analysis (an umbrella term for risk awareness, assessment, management and communication) provides an accountable and transparent framework for prioritizing actions in fisheries research and management, particularly in the broader context of the ecosystem approach to fisheries.
- There is documented evidence of risk analyses improving outcomes from fisheries management in Australia, Canada, South Africa and the United States. These analyses have considered potential fishery affects upon target species, non-target species, discarded species, threatened species, habitats and ecological communities.
- Effective application of risk-based approaches requires clear legislative and policy guidelines in which to frame the scope of any assessment. These guidelines should enable objectives or goals to be determined for the various components for the fishery so that risks with respect to these objectives or goals can be ascertained.
- The value-based nature of issues within fisheries requires recognition that risk-analysis is a decision support tool, not a decision-making tool. Existing decision-making processes (which may involve political discretion) should be supported by risk analyses.
- The importance of risk awareness and communication within risk analyses cannot be underestimated. There should be meaningful consultation with fishery stakeholders as part of any implementation plan.
- Risk-based approaches in Australia, Canada, South Africa and the United States have all required significant investment from scientific, managerial and industry experts. This investment will be associated with opportunity costs.
- A trade-off exists when managing fisheries within a risk-based paradigm. Fisheries can be managed at similar levels of risk by either: adopting intensive harvesting policies that require costly research, monitoring and management systems; or, harvesting moderately and having lower-cost research, monitoring and management systems. This concept is well established in single-species management but also generalizes to ecosystem-based approaches. Sainsbury (2004) has referred to this trade-off as the

"catch-management cost-risk" spectrum. Harvest control rules have been developed in Australia that manages fisheries across this spectrum[2].

- Risk assessment and risk management are generally seen as sequential processes that should be separated to ensure that they do not overly bias each other (for instance, the European Food Safety Authority does not undertake risk management at all, but only does risk assessment, to ensure separation of responsibilities with managing regulatory agencies)[3]. Alternatively risk assessment and risk management are seen as running in parallel, with transparent interactions between the processes, as advocated by FAO[4]. In some fields, such as software engineering, it is suggested that integration of risk assessment and risk management will lead to more effective and efficient solutions to problems[5]. This may apply in fisheries, where frequent reassessment following imposition of management leading to new management is an ongoing, interactive process.
- A tiered or hierarchical approach has been extensively used for risk analysis in Australia (Fletcher, 2005; Hobday, *et al.*, 2007). The first tier was a qualitative, but effective and efficient, screening process that considered the large numbers of potential affects of fisheries on the environment. Issues identified as being beneath some predetermined risk threshold (e.g. low risk) were not considered in more detail. Remaining issues were then assessed using a more detailed approach (which, in some cases, was fully quantitative). Issues that were determined to be of an unacceptable risk in the first tier were managed immediately.
- Vulnerability to risks in fisheries has several causes. Some is based on natural processes (stocks vary) or intrinsic uncertainty (we don't know how they vary). Management and social processes can also increase vulnerability (we need the fish, and may be catching too many for sustainable stocks), and may thus be used to assign some responsibility to particular actors in the system.
- Within the risk assessment framework there is a need for expert groups to tackle specific issues identified as being of concern. Such issues are likely to include quantitative stock assessment or harvest control evaluations. Equally in moving beyond a single species context or into novel manage-

[2] http://www.daff.gov.au/fisheries/domestic/harvest_strategy_policy

[3] "In the European food safety system, risk assessment is done independently from risk management. As the risk assessor, EFSA produces scientific opinions and advice to provide a sound foundation for European policies and legislation and to support the European Commission, European Parliament and EU Member States in taking effective and timely risk management decisions."
http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_aboutefsa.htm

[4] "National governments should acknowledge the importance of functional separation between risk assessment and risk management while ensuring transparent and appropriate interaction between them."
http://www.fao.org/docrep/MEETING/004/Y1941E.HTM

[5] Identification of potential faults and their solutions is carried out continuously by software engineers, who learn from both processes. "….risk assessment and management, as a process, will more and more assume the role of an overall cross-functional system integration agent."
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=531900

ment tools the input of experts from other relevant disciples (e.g. ecology, social science, economics, and policy analysis) would be essential. However, other areas may also need to be delegated in this fashion. For example, communicating a range of different uncertainties (qualitative and quantitative) without misleading and confusing is difficult. Stakeholder acceptance will be increased by involving stakeholders in decisions on which tasks to delegate to expert groups.

4 Specific recommendations

4.1 Operational guidelines

- Risk analysis is a transparent and accountable method for supporting precautionary ecosystem management.
- ICES/EU work on developing elements of risk-based approaches to fisheries management is well developed. Such methods have been demonstrated to be effective in other countries, and are now at a stage where they can be applied in ICES fisheries management.
- Any risk based approach to fisheries management within ICES areas should be consistent with international standards for risk analysis (e.g. AS/NZS 4360:2004, ISO 31000:2009), and address issues of likelihood, consequence and confidence.
- Research needs can be identified from a risk assessment, ideally with priorities determined by an analysis of the expected value of the additional information.
- The risk analysis framework should include mechanisms for evaluating performance, and be subject to review.
- Increase coordination and dissemination between relevant ICES expert groups, and between ICES groups and other bodies relevant to risk-based management of fisheries.

4.2 Further research

- Continue supporting projects investigating risk-based approaches to fisheries management such as PRONE, JAKFISH, ECOKNOWS, and DEFINEIT.
- Encourage research on the integration of risk analysis concerning the affects of fishing on fish communities and habitats.
- Review the use of novel tools (e.g. insurance and other financial tools, multi-sector management) that have the potential to improve the robustness of fisheries management to environmental, economic and social uncertainties.
- Further research within the ICES community should be based on "learning by doing". That implies that any case studies should be carefully planned including a detailed evaluation of the process and the usefulness of the outcome as a basis for advice.

5 Overview of previous reports

Previous reports of this Study Group have covered a range of different issues related to risk assessment in Fisheries. One point that was covered in different contexts in all of the previous reports (ICES, 2006; 2007; 2008) was the utility of the risk assessment process in highlighting which areas (stocks, data, management, etc) are high risk and thus deserving of increased resources (either research or management), and which ones can be considered to be low risk. The risk assessment therefore serves as a filter to prioritize research resources and management actions, and allows both qualitative and quantitative information to be used in an appropriate context. This allows for the breadth required for ecosystem coverage without sacrificing the depth currently present in many single species assessments.

In 2006 and 2007 reviews were conducted of a range of existing approaches to risk-based management in different countries and contexts. The first SGRAMA report (ICES, 2006) began with a review of several different approaches to risk assessment from around the world. Examples from the IPCC (2004), the EPA in the US (Environmental Protection Agency, 1998), the UKCIP report on climate adaption (Willows and Connell, 2003), the book "Risks and Decisions for Conservation and Environmental Management" (Burgmann, 2004), and the paper "A framework for risk analysis in fisheries decision-making" (Lane and Stephenson, 1998). In 2007 the review section was repeated and extended with a review of the paper ""Risk" in fisheries management" (Francis and Shotton, 1997). The report noted that a common feature of the different methods was an iterative approach, with past experience improving the decision-making process without demands for a perfected version being allowed to prevent progress. In addition, an extensive review was conducted in 2007 of the Australian approach to risk assessment in fisheries, and in particular the South African experience in implementing this approach (ICES, 2007). Several working documents were appended to the report giving details of the experience from South Africa on the adoption of risk assessment procedures and the functioning of Operational Management Strategies (Management Strategy Evaluations) within a risk analysis framework. The 2006 and 2007 reports also highlighted the multidisciplinary nature of risk assessments, and the need for broad participation in designing and conducting an effective risk assessment. The general context of risk analysis was considered to be highly appropriate to the management of ICES fisheries, and seen as an important potential step towards implementing the precautionary principle within an ecosystem management context. The current ICES handling of risk and uncertainty analysed and described. The report noted that the term "risk" was used in imprecise, and often contradictory, ways within ICES.

In 2008 SGRAMA (ICES, 2008) the different priorities in managing data rich and data poor stocks were also discussed and suggestions made as to how the risk assessment procedure gave a framework for combining the different work required on different stocks. There was a report on the Management Strategy Evaluations from the WGSAM, where uncertainty was a central part of the evaluations. An implementation of the risk assessment process in Sockeye Salmon in Canada was described. An overview of the aims of the PRONE EU project was provided. The Study Group also examined specific issues relating management reference points in relation to risk assessment and management. It was noted that such management reference points (e.g. B_{lim}, B_{pa}) are often set on an ad hoc basis, with scientific justifications often sparse or absent. The potential problems in setting B_{lim} to B_{loss} were also highlighted. It was recommended that part of any fisheries risk assessment process should consider the validity of the management reference points, and the implications of any uncertainties for the stock management. A series of specific recommendations were made for using limit reference points in managing fisheries within a precautionary approach and considering risk and uncertainties (ICES, 2008). The use of B_{lim}, and especially using ad hoc values or using B_{loss} as a proxy for B_{lim}, was considered to pose potential risks to fisheries. The SG recommended that risk assessments be conducted to identify if the use of B_{lim} as a management reference point and the value chosen for B_{lim} were compatible with the precautionary approach to the management of that fishery. Where resources permit an analysis of the harvest control rule using Management Strategy Evaluation or the Bayesian Approach was recommended. The SG also recommended that a broad risk assessment could be used to identify which stocks were most vulnerable to fishing, prioritize work to improve the understanding and management of these stocks, and thus provide a useful tool for managing "data poor" situations.

6 Related work

A number of different projects have been and are underway within Europe and ICES that relate to risk assessment in fisheries and within environmental protection as a whole. Some of these are briefly described below, and we consider it important to take the expertise and experience from these projects into wider use in ICES fisheries management.

6.1 PRONE

The PRONE project (Precautionary risk methodology in fisheries) was an EU-funded research project whose main aim was to improve the identification, assessment, management and communication of risk in fisheries management and to provide an integrated approach including biological, economic and social objectives. PRONE did this by developing new methodology, reviewing approaches taken elsewhere and showing how they could be adapted for use in a European fisheries context. The SGRAMA recognized the significance of the work of PRONE and the many important steps it has taken towards developing and implementing a risk framework for fisheries in Europe.

Reviews of the risk methodology in other fields made it obvious that fisheries should adapt methodological approaches from other scientific fields, especially in regard to an EAFM. In addition, there is a long history in utilizing models for stakeholder communication in other fields. For example, the EU Marine Strategy and Water Framework Directives ask for methods applicable to stakeholder communication, and fisheries could be linked to these activities (see JAKFISH below). Further details are in Annex 2.

6.2 PRONE: Fisheries insurance concept

The PRONE project addressed aspects of uncertainty in fisheries. Uncertainty can cause behaviour that adversely affects the sustainability of stocks, for example increasing effort on falling catches to maintain revenue. Many responses to uncertainty in fisheries are retrospective, for example changing TACs after stocks appear to have fallen. By contrast, insurance is prospective, looking ahead to mutually perceived risks and responding to these in advance through the establishment of premiums and claims processes. Insurance is based on modelled risks and behaviour, which are accepted by all parties to the insurance. In PRONE a stochastic model was developed to illustrate how insurance funds could protect revenue and encourage increased sustainability of fisheries, and improve compliance and enforcement for fisheries regulation. The reality of these models is less important than their general acceptance for the purpose, but periodic reviews would help to bring the accepted risk/insurance model nearer to reality.

Insurance may transform the governance framework. In agricultural examples examined by PRONE insurance has led to the establishment of more convergent objectives and behaviour among stakeholders (industry, regulators, and consumers). This occurred through changes in responsibility that shifted the burden of risk, and allowed increased trust between regulators, industry, and scientists. It also provided incentives for industry to pay for information and dissemination that reduced uncertainty (lowering premiums).

A major obstacle to any insurance programme is overexploitation in most capture fisheries (FAO, 2005b). Insurance could reduce the overexploitation that may result from responses to uncertainty, such as increasing effort on falling catches. Insurance is only likely to be a useful tool within a fishery that is either well-managed or willing to be well managed. The opportunity for insurance may be an incentive to moving to a well-managed fishery because there is a greater expectation of sustainability.

An insurance model provides a transparent, logical method of converting risk into a convenient (monetarised) metric. The principles of an insurance approach to uncertainty (and not necessarily an actual insurance scheme) make it possible to place a value on the various components of uncertainty that arise from lack of accuracy or other causes of non-credibility. It may also be a way of introducing a value for mutual trust among stakeholders (showing them what it costs to disagree).

6.3 Plant health risk analysis approaches

The PRATIQUE[6] project (Baker *et al.*, 2009) is a European effort to enhance the pest risk analysis process applied to exotic pests affecting agriculture and natural environments. The approach used here represents one approach to risk analysis that could be relevant in designing risk-based fisheries management within ICES. Key issues identified in this project include the need for a consistent framework for assessing the likelihood and consequences of exotic pests and linking pest risk management measures to risk assessments in a more rational and transparent process. Consistency is difficult because of the wide range of taxa involved as risk agents and the diverse pathways and receptors for these risks. Consistency is important because of the trade implications and international treaty obligations that are affected by responses to these diverse risks. A specific focus of the project is the consistency and harmonization of the pest risk analysis process used by the European and Mediterranean Plant Protection Organisation (EPPO)[7], which uses a framework from the International Plant Protection Convention (IPPC)[8] (IPPC, 2007). EPPO carries out species risk assessments of pests that have been requested by its member states. This is done by convening a panel of risk experts, usually for five days, during which a consensus is developed on the component attributes of a pest threat and appropriate management responses, using a common risk assessment and management scheme[9]. This process generates a risk assessment and management report in a standard format for publication and action by member states.

[6] https://secure.csl.gov.uk/pratique/index.cfm

[7] http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm

[8] https://www.ippc.int/IPP/En/default.jsp

[9] http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_template_2009.doc

In Great Britain invasive species risks are assessed through the Non-native Risk Analysis Panel (NNRAP) of the Non-native Species Secretariat (NNSS)[10] using a method based on that described by Baker *et al*. (2007). The NNRAP/NNSS establishes species for which there is concern, commissions' risk assessments from experts with experience of the relevant taxonomic group, and acts as a peer review body that ensures a consistent standard for assessments. Alien species risks are novel and cannot be tested experimentally so the assessments are often quite subjective, but must still have sufficient rigour to ensure that appropriate responses can be justified. The NNSS uses a risk assessment template adapted from the one developed by EPPO in which risk assessors are required to score approximately 50 individual components of risk related to entry, establishment, spread and affect. Each component is scored on a five point scale (see appendix) for either likelihood or magnitude, as appropriate, and the assessor indicates the level of confidence on a four point scale (see appendix). Each of these scales is clearly and consistently defined throughout the system. Each component score must be justified by documentation from the risk assessor. An overall score is given by the risk assessor for each of the four components, with entry and establishment expressed as likelihood and spread and impact as magnitude. The peer review process then checks that the overall subjective component scores is convincingly justified by the scoring of individual questions and that these are adequately documented. The process iterates with the risk assessor until a consensus is reached. The NNSS prepares a risk assessment summary in a standard format which is passed to the executive agencies responsible for implementing invasive species policy, with relevant options for management. No explicit weighting is given to component scores, but key components that contribute to the overall assessment score are highlighted in the summary. The summary includes a risk profile showing a cumulative probability distribution of possible impact derived from the summary likelihood, magnitude and confidence scores of the risk assessors. By using a consistent risk assessment process comparative risk profiles can be presented for very different species, allowing agricultural and environmental policy to be consistently applied.

6.4 EU JAKFISH project

The EU project JAKFISH (Judgement and Knowledge in Fisheries Involving Stakeholders) is currently building on the work carried out in PRONE towards more defined institutions, practices and tools to support governance and management decision under uncertainty. The experiences of various fora implementing participatory decision-making that deals with uncertainty, complexity and ambiguity is being analysed in order to map how scientific information is being used in the process by the various actors and institutions involved. JAKFISH attempts to answer various questions on the skills, tools and institutions necessary for participatory decision-making to proceed based on the best scientific advice and the perceptions of multiple actors, and how that framework can best support the necessary community and the required processes of quality control, transparency and accountability.

6.5 Indicators

Risk management in fisheries can be undertaken using a wide range of options available to fishery managers. These options include licensing regimes, catch limits, gear

[10] http://www.nonnativespecies.org/

regulations, compliance strategies, minimum and maximum legal sizes, temporal and spatial closures, bycatch limits, discard bans and possession limits. Such regulatory strategies should be supported by consultative and educational arrangements. In almost all cases, these management options will reduce risks by decreasing the likelihood of outcomes that are inconsistent with the objectives for the fishery.

Risk management has several characteristics that may make it differ from the usual strategies used in fisheries management. First, as a consistent assessment process has been used to identify and rank risks that have the potential to impact objectives, there should be better prioritization of resulting managerial actions. Second, if this assessment process has been done with effective consultation and communication (i.e. transparency), then the priority actions should have improved support from stakeholders. The third dimension of risk management is that, in some cases, management may be used which is designed to provide improved outcomes in an uncertain system, without the need to understand how and why the system is being impacted. For example, insurance is a risk management strategy, but the purpose of insurance is not to mitigate particular events, but lessen the negative outcomes of those events should they occur.

In all applications of risk management in fisheries there must be performance measures defined to determine the success or otherwise of management actions with respect to achieving agreed objectives. This requires the development of appropriate indicators or reference points against which performance can be measured. This principle applies to valuable single-species fisheries, multispecies fisheries and fisheries managed in a broader ecosystem context (and everything in-between). Indicators and reference points are both required to define management performance and a range of existing and novel methods are available or are being developed and evaluated (IMAGE, PRONE, JAKFISH, SGHERWAY).

Experience in South Africa, Australian and New Zealand has indicated that codified decision rules (or harvest control rules based upon reference points) can improve fishery outcomes by providing certainty of process to industry and government. The performance of harvest control rules can be evaluated with respect to a number of criteria including biological and ecological sustainability, economic performance, social acceptability and food security.

Since 1998, ICES advice on fisheries management consists of a dual system of limit and "precautionary approach" reference points, the latter providing a buffer to safeguard against natural variability and uncertainty in the assessment, and ensuring that limit reference points are avoided with high probability (ICES, 2007). Cadrin and Pastoors (2008) noted that of the 137 ICES management units for which advice is provided by ICES, only 17% actually had the necessary estimates to implement the precautionary control rule, while 61% had no estimates of reference points at all. In addition the World Summit on Sustainable Development (WSSD; COFI, 2003) commits signatories to maintain or restore stocks to levels that can produce the maximum sustainable yield (MSY) by 2015.World Summit on Sustainable Development (WSSD). Although target reference points have been suggested by ICES in some cases but have they have not been formally included in the advisory practice. Therefore while there is a need for ecosystem or community indicators there is also still a need to develop reference points for exploited fish stocks.

In a single species context, indicators/reference points are an important part a monitoring, assessment and management procedures. The choice of indicators/reference is paramount: as they must have enough fidelity to detect and differentiate between changes in the environment or because of exploitation. In data-rich fisheries, an indicator such as such as the average weight of the landed fish or the proportion of older fish can be used as part of a portfolio of monitoring methods, and fisheries-independent survey-based indicators such as those developed by the EU-sponsored project FISBOAT may be suited for this situation. However evaluation of the robustness of any indicators used for management is essential, because an indicator such as mean size landed may not actually measure a property of the population, as it can be a function of changes in targeting by fleets and management regulations. Also credibility with stakeholders is important, for example where fishermen dispute survey results because survey stations and gear used differ from fishing locations and commercial gears.

One tenet of the ecosystem approach to fisheries (EAF) is to ensure that fishing effects on fisheries and the environment are sustainable. Systems based on indicators and reference points are usually used to track progress towards sustainability. Meeting sustainability objectives for fisheries and the environment requires knowledge of the trade-offs between catches and fishing impacts. In Europe, the need for this knowledge is particularly pressing following the adoption of the Marine Strategy Framework Directive (MSFD; EC 2008a), since one of the main aims of the MSFD is to achieve Good Environmental Status (GES) for ecosystem components and attributes (e.g. populations, communities, foodwebs, seabed habitats, biodiversity) that are impacted by fishing. Knowledge of trade-offs between multiple objectives i.e. of simultaneously meeting environment and fisheries objectives, is required to inform the selection of reference points and to ensure that any incompatibilities and their consequences are recognized at the outset. If knowledge of these trade-offs does not inform decisions about the definitions of GES then there are risks that (i) all objectives could not be met simultaneously and (ii) the policies will not be regarded as workable or credible by stakeholders.

For data-limited fisheries, finding an empirical indicator of sufficient quality remains a challenge. Sized based models provide a way of addressing these issues and evaluating appropriate indicators in a cost-effective and timely manner. For example if all 'populations' in the North Sea are fished at MSY what would be appropriate community indicators (ref)? The next problem will be to develop appropriate operational monitoring and management regimes or procedures. Such models will be important in proposing and evaluating appropriate indicators for use in management using management strategy evaluation (MSE). Especially if combined with single species MSE.

Indicator maybe used with a statistical process control method such as the cumulative sum (or CUSUM) method, in order to remove subjectivity in the detection of out-of-control signals in order to stabilize the fishery via management procedures. Work currently in progress is evaluating the application of simple HCRs to the CUSUM monitoring of changes in catch-based and other indicators in simulated fisheries, both for single-species and community-based management.

The EU project DEFINEIT aims to develop resource indicators that combine economic, social and biological indicators. The traditionally used indicator of economic activity is the operating economy of the fishing fleet (landing value, profit, employment). However, such indicators neither relate directly to the benefit for the whole society nor are they necessarily sustainable. Therefore, relevant indicators for the economic return in fishing must be based on a sustainable socio-economic measure. Sustainable socio-economic return does, however, only state the present return to society of the existence of a fishery, not the economic potential of the fishery. To this aim, the Maximum Economic Yield must be determined and the socio-economic return associated with a move to the MSY and simultaneous minimization of fishing fleet determined. To allow fisheries to conform to dynamic MSY levels, adaptive management must be planned within agreed governance structures and the rules for governance must be robust and simple to interpret. In terms of economic indicators it is furthermore important to take a stochastic approach, because variance and uncertainty are critical issues in relation to the economic performance of natural resource systems.

6.6 Fisheries systems, mixed fisheries and multispecies issues

Single species, single fisheries, models or assessments can often miss key factors of the fisheries or ecological system. In addition the adaptive behaviour of fishers in response to management changes (especially in a mixed fisheries context) may lead to well-intentioned measures having unexpected outcomes. All of these issues should be considered to represent potential risks in fisheries management. The risk assessment process can identify where mixed fisheries, fisheries governance or multispecies issues may be important factors, and help identify appropriate models or other tools for dealing with these issues. There are current ICES working groups considering multispecies (WGSAM), mixed fisheries (WGMIXFISH), ecosystem effects (WGFE) and general fisheries systems (WGFS) issues. These working groups provide a rich base of expertise within ICES that could be utilized if a risk-analysis approach to ecosystem-based management were to be adopted.

If a risk assessment is conducted with a very broad framework encompassing a fisheries system as a whole, including socio-economic issues, we are faced with challenges such as the development of good performance criteria for a fisheries system. Please note that a risk assessment will in itself be a part of a fisheries system and used for the "production" of knowledge. The obstacles to achieve consensus on objectives (Degnbol and McCay, 2006) are likely to influence the risk assessment process, and in particular the more "value" laden aspects such as the consequences of certain events. It can be useful to treat the inability to describe and even understand linkages in a fisheries system as a risk in itself, but the consequences of this "certain" event will never be predictable because we are actually dealing with the "unknown unknowns" (Myers, 1995, Rumsfeld, 2002).

6.7 Fisheries risk assessments relative to oil industry risk assessments

One area where risk assessments are currently used in a marine context is in oil exploration and exploitation. Both within ICES areas and outside, oil industry conducts extensive risk assessments to support decisions on approving or rejecting developments or to modify projects to reduce environmental impacts. From a fisheries point of view, it would be advantageous to draw on the expertise and competence developed in these oil related contexts. More generally if an aim of management is to move towards ecosystem approaches to fisheries management, then it is important that different impacts on the ecosystem (such as oil or fisheries) can be assessed in a comparable way. There are a number of projects, in the Barents Sea, the Baltic and others, which aim to integrate oil spill risk assessment with fisheries modelling to produce an overall assessment of the impacts on the fisheries system. One such project in Norway is described in Annex 2.

6.8 Vulnerability in risk assessment

The concept of vulnerability encompasses a range of properties associated with the receptor of a *specified* risk that makes either or both likelihood and/or magnitude greater (Brooks, 2003). The concept is widely discussed in risk literature, such as that on climate change. It is sometimes divided into three broad sub-concepts:

- Biophysical vulnerability – the propensity for an agent to cause harm to a receptor (a property of the intrinsic relationship between the *risk source* and *risk receptor*)
- Management vulnerability - management actions that directly favour likelihood or consequences (often associated with the *risk pathway* between sources and receptors)
- Social vulnerability – human factors that reduce the ability of a *risk receptor* to cope with interactions with *risk sources* (so, in addition to the biophysical and management vulnerability, this could also lead to an increased likelihood and/or magnitude of loss)

Going beyond the scope of present risk assessment this could lead to an objective assessment of the shared responsibility for the risk and the potential for co-responsibility in the management of the risk. This may become increasingly important as governments move to incorporate greater cost and responsibility sharing. Bio-ecological vulnerability deals simply with natural factors that contributes to risk (likelihood and/or magnitude); management vulnerability deals with management that contributes to risk, but without attaching any responsibility to it (it is descriptive of the results of management rather than the reasons for management); and social vulnerability tries to determine if there is some social responsibility (which might in the extreme be considered "blame") for putting the system at risk. Stakeholder involvement in the process would be needed to help establish causes and results of social vulnerability.

Bio-ecological and management vulnerability are already implicitly included in many risk assessment schemes. However, social vulnerability may also be a key issue, both in assessing the level of risk and establishing a basis for co-responsibility in risk management. Explicit vulnerability analysis would help to determine what natural, management or social factors contribute to susceptibility to risk (likelihood or impact) and how these should be taken into account in policies for assigning responsibility in risk management.

7 Experience of ecological risk assessment in Australia

7.1 Background

Ecological risk assessment (ERA) has been used extensively in Australia as part of the strategic environmental assessment of export fisheries as required by the federal *Environment Protection and Biodiversity Conservation Act* 1999[11]. Three methods have been developed and applied: The National ESD Reporting Framework (NESDRF); the NSW Quantitative ERA (NSWQERA) method and Ecological Risk Assessment for Effects of Fishing (ERAEF). All three approaches have been used to prioritize research projects and management responses for Australian fisheries. In a recent review

[11] www.environment.gov.au/epbc/assessments/fisheries.html

of risk-based approaches for Australian fisheries, Scandol *et al.* (2009) provided a detailed summary of these three methods. This review project also developed a series of national guidelines about the application of risk-based approaches for data-poor fisheries and benchmarked all Australian jurisdictions with respect to these guidelines. Readers should also consult Astles (2008), which is review of recent developments of ERA in marine fisheries and also includes a list of elements needed for any method used to estimate ecological risk in such systems.

7.2 The National Ecologically Sustainable Development Reporting Framework (NESDRF)

This framework has been extensively documented by Fletcher *et al.* (2002, 2003, 2005) and Fletcher (2005, 2006, 2008). The ERAEF is suitable for performance reporting on the wide spectrum of issues associated with ecologically sustainable development[12] (which is a superset of the concepts associated with ecosystem-based fisheries management or the ecosystem approach to fisheries). A key component of the NESDRF is a qualitative risk assessment of the potential impacts on fisheries upon retained species, non-retained species and the general ecosystem. The risk assessment processes was developed using the Australian and New Zealand standards for risk management (AS/NZS 4360:2004, Risk Management.) and involved expert and literature-based determination of the consequence and likelihood of adverse outcomes associated with fishing activities. Risk was determined using a standard risk matrix. Outcomes which were greater than "low risk" were then subject to more rigorous performance management with indicators, reference points and performance measures. The West Australian Department of Fisheries has provided numerous examples of such reports and assessments[13].

7.3 NSW Quantitative ERA (NSWQERA) Method

The NSWQERA method has been described in detail by Astles (2006, 2009). This approach was developed in response to legislative requirements in NSW and places emphasis on the estimation of likelihood rather than consequence. Consequences were taken to be specified by the provisions within several pieces of State legislation as well as the Commonwealth *EPBC Act*. Likelihood (or risk) was then estimated by the combination of resilience (based on biological characteristics of the species or habitat) and the fishery impact profile (based upon the characteristics of the fishery). Risk management planning included an evaluation of which aspects of the fishery impact profile could be altered to reduce risks to an acceptable level. These ecological risk assessments were embedded within a detailed strategic environmental assessment of NSW commercial fisheries which also included consideration of social and economic impacts. Examples of these environmental assessments are available from the New South Wales Government website[14].

7.4 Ecological Risk Assessment for Effects of Fishing (ERAEF)

This tiered approach involved three levels of assessment ranging from efficient qualitative methods, to semi-quantitative methods, to detailed fully quantitative models

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[12] The national portal for this approach is at www.fisheries-esd.com

[13] www.fish.wa.gov.au/docs/mp/index.php?0206

[14] www.dpi.nsw.gov.au/fisheries/commercial/ea

(Hobday *et al.*, 1997). The framework was developed by CSIRO in response to ESD reporting requirements and the Commonwealth implementation of ecosystem based fisheries management by the Australian Fisheries Management Authority. Level 1 of this ERA process was a Scale Intensity Consequence Analysis (SICA) which aimed to identify hazards (fishing activities or external activities) which would lead to a significant impact on species, habitats or communities. Level 2 ERA required the application of semi-quantitative productivity-susceptibility assessment methods (see Stobutzki 2001a; 2001b). Level 3 ERA was a broader concept which included the application of full quantitative models such as traditional quantitative stock assessment, management strategy evaluation and ecosystem modelling. A new fully quantitative approach has recently been developed by Zhou *et al.* (2007, 2008, 2009) which is now used in many Level 3 assessments. Examples of the application of ERAEF are available from the Australian Fisheries Management Authority website[15].

7.5 Final Comments on ERA in Australian Fisheries

The environmental assessments with the associated ecological risk analyses completed in Australia have had extensive and wide ranging impacts on the management of fisheries. These assessments were initiated by a complex array of policy and legislative developments over a number of years and across multiple jurisdictions (see Scandol *et al.*, 2005; Fletcher 2008). Many of these developments were associated with Australia's ratification of international agreements such as the Convention on Biological Diversity[16].

These assessments have required a significant investment of time and resources by scientific, managerial and policy staff in a diverse range of government and non-government institutions. All assessments included extensive consultation with stakeholders during their development and review. Furthermore, as these environmental assessments were extensions to existing environmental impact legislation, key features of such legislation (such as defined opportunities for public comment) were mandatory.

The majority of stakeholders and personnel involved with these assessments would agree that the risk analyses have been a critical component of these assessments and the whole exercise has been extremely worthwhile. Most people would also, however, agree that the environmental assessments and ecological risk analyses were more difficult and took more time than originally envisioned.

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[15] www.afma.gov.au/environment/eco_based/eras/default.htm

[16] www.cbd.int

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9 References

AS/NZS (2006). Environmental risk management - Principles and process. Standards Australia and Standards New Zealand, HB 203:2006.

Astles, K. L. 2008. A systematic approach to estimating ecological risks in marine fisheries. *CABI Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*: 16.

Astles, K. L., Holloway, M. G., Steffe, A., Green, M., Ganassin, C. 2006. An ecological method for qualitative risk assessment and its use in the management of fisheries in New South Wales, Australia. *Fisheries Research* **82**: 290-303.

Astles, K.L., Gibbs, P.J., Steffe, A.S., Green, M. 2009. A qualitative risk-based assessment of impacts on marine habitats and harvested species for a data deficient wild capture fishery. *Biological Conservation* **142**(11):2759-2773

Baker, R.H.A., Battisti, A., Bremmer, J., Kenis, M., Mumford, J., Petter, F., Schrader, G., Bacher, S., DeBarro, P., Hulme, P.E., Karadjova, O., Lansink, A.O., Pruvost, O., Pysek, P., Roques, A., Baranchikov, Y., Sun, J.H. 2009. PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union. *EPPO Bulletin*, 39:87-93. ISSN: 0250-8052

Baker, R.H.A., Black, R., Copp, G.H., Haysom, K.A., Hulme, P.E., Thomas, M.B., Brown, A., Brown, M., Cannon, R.J.C., Ellis, J., Ellis, M., Ferris, R., Glaves, P., Gozlan, R.E., Holt, J., Howe, L., Knight, J.D., MacLeod, A., Moore, N.P., Mumford, J.D., Murphy, S.T., Parrott, D., Sansford, C.E., Smith, G.C., St-Hilaire, S., Ward, N.L. 2007. The UK risk assessment scheme for all non-native species. *In:* Rabitsch, W., F. Essl and F. Klingenstein (Eds.): Biological Invasions – from Ecology to Conservation. *NEOBIOTA*, 7:46-57.

Brooks, N. 2003. Vulnerability, risk and adaptation: A conceptual framework. Working Paper 38, Tyndall Centre, UEA, Norwich, UK. 16pp. http://www.tyndall.ac.uk/content/vulnerability-risk-and-adaptation-conceptual-framework

Burgmann, Mark A. 2004. Risks and decision for conservation and environmental management. Cambridge University Press. ISBN 0 521 54301 0.EPA. 1998. Guidelines for Ecological Risk Assessment. US

Degnbol, P., and McCay, B. J. 2006. Unintended and perverse consequences of ignoring linkages in fisheries systems. ICES Journal of Marine Science, 64: 793–797.

Environmental Protection Agency, Risk Assessment Forum, Washington, DC, EPA/630/R095/002F, 1998. (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12460). Francis, R. I. C. C., and Shotton, R. 1997. "Risk" in fisheries management: a review. Can. J. Fish. Aquat. Sci. Vol. 54, 1997, Canada.

FAO. 2005a. Putting into practice the ecosystem approach to fisheries, Food and Agriculture Organization of the United Nations Rome: 82 pp, ISBN: 9789251053966

FAO. 2005b. Topics Fact Sheets. Fishing capacity. Text by Rebecca Metzner. *In:* FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 30 January 2009]. http://www.fao.org/fishery/topic/2898/en

FISBOAT: Fishery independent survey-based operational assessment tools: documents available online at http://www.ifremer.fr/drvecohal/fisboat/.

Fletcher, R., Chesson, J., Fisher, M., Sainsbury, K. J., Hundloe, T. J. 2002. National ESD reporting framework for Australian fisheries. The 'How To' guide for wild capture fisheries. FRDC Project 2000/145. Canberra, Australia.

Fletcher, W. J. 2005. The application of qualitative risk assessment methodology to prioritize issues for fisheries management. *ICES Journal of Marine Science* **62**: 1576-1587.

Fletcher, W. J. 2006. Implementing ecosystem approaches to fisheries management: lessons learned from applying a practical EAFM framework in Australia and the Pacific In 'Proceedings of Conference on Implementing the Ecosystem Approach to Fisheries', Bergen, Norway pp. 1-15: City.).

Fletcher, W. J. 2008. Implementing an ecosystem approach to fisheries management: lessons learned from applying a practical EAFM framework in Australia and the Pacific. *In* 'The Ecosystem Approach to Fisheries'. (Eds Bianchi, G. and Skjoldal, H. R.) pp. 112-124. (FAO: Rome.).

Fletcher, W. J., Chesson, J., Sainsbury, K. J., Hundloe, T., and Fisher, M. 2003. The ESD assessment manual for wild capture fisheries. FRDC Project 2002/086, Canberra, Australia.

Fletcher, W. J., Chesson, J., Sainsbury, K. J., Hundloe, T. J., and Fisher, M. 2005. A flexible and practical framework for reporting on ecologically sustainable development for wild capture fisheries. *Fisheries Research* **71**: 175-183.

Hobday, A. J., Smith, A. D. M., Webb, H., Daley, R., and Wayte, S. 2007. Ecological risk assessment for the effects of fishing: Methodology. CSIRO, 174 pp.

ICES. 2006. Report of the Study Group on Risk Assessment and Management Advice (SGRAMA), 18–21 April 2006, ICES Headquarters, Copenhagen. ICES CM 2006/RMC:04, Ref. LRC, ACFM, ACE, ACME. 75 pp.

ICES. 2007. Report of the Study Group on Risk Assessment and Management Advice (SGRAMA), 5–9 February 2007, Cape Town, South Africa. RMC:02. 68 pp.

ICES. 2008. Report of the Study Group on Risk Assessment and Management Advice (SGRAMA), 1–5 December 2008, ICES Headquarters, Copenhagen. ICES CM 2008/RMC:09. 36 pp.

IPCC. 2004. IPCC Workshop on Describing Scientific Uncertainties in Climate Change to Support Analysis of Risk and of Options. Intergovernmental Panel on Climate Change, Ireland, 11–13 May, 2004.

IPCC. 2005. Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties. Intergovernmental Panel on Climate Change, Geneva, Switzerland. 4pp . http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf

IPPC. 2004. Pest risk analysis for quarantine pests including analysis of environmental risks. ISPM No 11 (Rev), International Plant Protection Convention, FAO, Rome, Italy. 26pp. https://www.ippc.int/servlet/CDSServlet?status=ND0xMzM5OSY2PWVuJjMzPSomMzc9a29z

Lane, D. E., and Stephenson, R. L. 1998. A framework for risk analysis in fisheries decision-making. ICES Journal of Marine Science, 55: 1–13.

Milcendeau, D. (ed.), 2009. "Fish Stock Assessments Using Surveys and Indicators": special issue of *Aquatic Living Resources*, 22(2): 119-254. Contains papers and outputs from the FISBOAT project.

Mumford, J.D., Leach A. W., Levontin P., Kell L. 2009. Insurance mechanisms to mediate economic risks in marine fisheries. *ICES Journal of Marine Science*, 66:950-959; doi:10.1093/icesjms/fsp100

Myers, N. 1995. Environmental Unknowns. SCIENCE Vol. 269 (July 21, 1995), pgs. 358-360.

Rumsfeld, D. 2002. Statement made February 12. 2002 at news briefing while Secretary of Defense in the George W. Bush administration.

Scandol, J. P., Ives, M.C., and Lockett, M. 2009. Development of national guidelines to improve the application of risk-based methods in the scope, implementation and interpretation of stock assessments for data-poor species (Final Draft). FRDC Project No. 2007/016, NSW Department of Primary Industries, 182pp.

Stobutzki, I., Miller, M., and Brewer, D. 2001a. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. *Environmental Conservation* **28**: 167-181.

Stobutzki, I. C., Miller, M. J., Heales, D. S., and Brewer, D. T. 2001b. Sustainability of elasmobranchs caught as bycatch in a tropical prawn (shrimp) trawl fishery. *Fishery Bulletin* **100**: 800-821.

Willows, R., and Connell, R. Eds. 2003. Climate adaptation: Risk, uncertainty and decision-making. UK Climate Impacts Programme (UKCIP) Technical Report. UKCIP, Oxford.

Zhou, S., and Griffiths, S. P. 2008. Sustainability Assessment for Fishing Effects (SAFE): A new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. *Fisheries Research* **91**: 56-68.

Zhou, S., Griffiths, S. P., and Miller, M. 2009. Sustainability assessment for fishing effects (SAFE) on highly diverse and data-limited fish bycatch in a tropical prawn trawl fishery. *Marine and Freshwater Research* **60**(6): 563-570.

Zhou, S., Smith, A. D. M., and Fuller, M. 2007. Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Australian Fisheries Management Authority.

Annex 1: List of participants

Name	Address	Telephone/Fax	Email
Daniel Howell *Interim Chair*	Institute of Marine Research PO Box 1870 N-5817 Bergen Norway	+47 55 23 86 79	danielh@imr.no
Laurence Kell	ICCAT SECRETARIAT Corazón de María, 8. 28002 Madrid, Spain	Phone: 34 914 165 600 Fax: 34 914 152 612	laurie.kell@iccat.int
Knut Korsbrekke *Absent Chair*	Institute of Marine Research Nordnesgt 33 PO Box 1870 N-5817 Bergen Norway	+47 55 23 86 38 +47 55 23 86 87	knut.korsbrekke@imr.no
John Mumford	Centre for Environmental Policy Imperial College London Silwood Park Ascot, Berkshire SL5 7PY UK	+44 207 594 2206	j.mumford@imperial.ac.uk
Deepak George Pazhayamadom	Department of Zoology, Ecology and Plant Science (ZEPS), University College Cork (UCC), Distillery Fields, North Mall, Cork, Ireland	353 (0)21 490 4676	deepakgeorgep@student.ucc.ie
James Scandol	Zetafish Pty Ltd 404/2-4 Mount Street Walk Pyrmont NSW 2009 Australia	+ (612) 9566 2639	jscandol@hotmail.com
Graeme Thorn	Department of Biological Sciences, University of Essex, Wivenhoe Park, Colchester, Essex, CO4 3SQ, UK	+44 1206 873043 +44 1206 873029	gthorn@essex.ac.uk
Iago Mosqueira	Systems Modelling Cefas Pakefield Rd. Lowestoft, NR33 0HT UK	+44(0)1502 558003	iago.mosqueira@cefas.co.uk

Annex 2: Overview of related projects

Indicators, management and risk assessment: Statistical Process Control (SPC) and Risk Assessment

Statistical Process Control (SPC) is a well-developed method for the control of processes where there is inherent variability (Hawkins and Olwell, 1998), such as in manufacturing. In an SPC approach, a process indicator is monitored (either continuously or at discrete time points) and if the indicator displays an 'out-of-control' signal (in some objective sense), then a management decision is made to bring the process back into control (Figure 1). Two of the most well-known methods of SPC are the Shewhart control chart and the cumulative sum (or CUSUM) control chart. In the Shewhart chart, the raw value of the indicator is plotted, and if the value is outside the control range (normally taken to be the controlling/target mean plus/minus three standard deviations) then a signal is triggered. For a CUSUM chart, the deviation of the current observation from the controlling mean is added to the value of the CUSUM from the previous observation, and an out-of-control signal is triggered if the CUSUM reaches outside the control range. A common variation of the CUSUM is to use an allowance parameter in which inherent random deviations of the indicator below a specified level are considered to be less important than detecting a shift in the mean of the process.

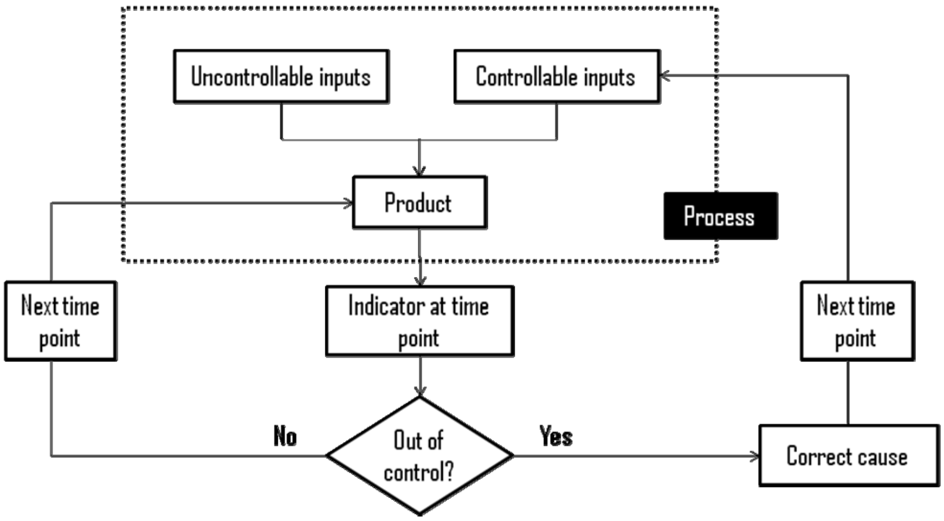

Figure 1. Flow chart showing the statistical process control method for management.

CUSUM performs better than the Shewhart chart when a persistent but gradual change in the underlying process occurs: on average it will show a signal earlier than the corresponding Shewart chart due to its cumulative nature (Hawkins and Olwell, *op. cit.*), and hence is more suited to ecological problems where factors such as overharvesting or gradual environmental change can occur. Ideally, the decision thresholds and allowance parameter should be set to maximize the specificity and the sensitivity of the method, by maximizing the in-control average run length (IC-ARL: average length of time before a signal is falsely triggered if the process remains in control), and minimizing the out-of-control average run length (OC-ARL: average length of time before a signal is correctly triggered if the process shifts out of control)

Using indicators to monitor fisheries is not a new concept, for example, the FISBOAT project has used spatial survey-based abundance indicators to detect changes in the fishery (see documents from the FISBOAT project, also see Milcendeau, 2009). However, the application of control charts (more specifically CUSUM) to fisheries data are relatively new (see Scandol, 2003, 2005) and documents from FISBOAT project, where it is used as part of a portfolio of monitoring methods). More recently, work is in progress on the use of CUSUM on catch-based indicators (such as the catch number age proportions and catch weight age proportions) with simple harvest control rules to determine whether management using CUSUM as a decision-triggering tool can work towards the stabilization of yields.

The approach followed by the FISBOAT project is to split the analysis of the indicator series into two phases, I and II. In Phase I, the fishery is considered 'in-control' and values of the controlling mean and standard deviation for each indicator can be calculated: in phase II, the values of the allowance parameter and threshold values are tuned to maximize the IC-ARL and minimize the OC-ARL. This procedure is therefore more useful in relatively data-rich fisheries, where these periods are more easily determined. For data-limited situations, where there is incomplete knowledge of stock dynamics, CUSUM can be used to objectively detect relative changes in empirical indicators such as the average length of caught fish or proportion of older fish: however, determining the relevant control parameters for the application of the CUSUM method is more difficult in this case, and may need to rely more on expert knowledge.

CUSUM can be used, as in the FISBOAT project, as a means of reviewing historical stock status, and as part of a review process to determine whether the present reference points (such as B_{lim} and B_{pa}) remain applicable for stocks where the limits are defined.

References:

FISBOAT: Fishery independent survey-based operational assessment tools: documents available online at http://www.ifremer.fr/drvecohal/fisboat/.

Hawkins, D. M., and Olwell, D. H. 1998. *Cumulative sum charts and charting for quality improvement*. Springer-Verlag. New York.

Milcendeau, D. (ed.), 2009. "Fish Stock Assessments Using Surveys and Indicators": special issue of *Aquatic Living Resources*, 22(2): 119-254.

Scandol, J. P. 2003. "Use of cumulative sum (CUSUM) control charts of landed catch in the management of fisheries." Fisheries Research 64(1): 19-36.

Scandol, J. P. 2005. "Use of Quality Control Methods to Monitor the Status of Fish Stocks." 213-234pp in Kruse, G. H., Gallucci, V. F., Hay, D. E., Perry, R. I., Peterman, R. M., Shirley, T. C., Spencer, P. D. and Wilson, B., and Woodby, D. (eds.): Fisheries Assessment in Data-Limited Situations. Alaska Sea Grant AK-SG-05-02. ISBN 1-56612-093-4.

Norwegian Decision Support Tool description

An existing culture of risk assessments is embedded in the petroleum industry in a number of countries, including Norway. These risk assessments as used in deciding if a project should go ahead, as well as in risk mitigation exercises to minimize the environmental impact of the development. As oil development expands into new, and potentially more environmentally sensitive, regions it is important to produce risk assessments based on the best available knowledge.

A project to develop a Decision Support Tool for use in the oil industry is being developed by a consortium led by the ARCTOS network of marine ecologists, the Institute of Marine Research in Bergen (IMR), and the Centre for Ecological and Evolutionary Synthesis (CEES), University of Oslo. The project aims to integrate oceanographic, plankton, larval and fisheries models into the existing risk assessment tools developed by Statoil. This will improve the level of biological realism in the risk assessment process, and reduce the uncertainties involved. The project will link existing models in order to track the impacts of an oil spill from the estimate of size, location and duration of a spill, through effects on plankton and larvae, and on the impact on the fish populations and fisheries of the Barents Sea. Although a great deal of complexity exists in each model, the links between them are being kept simple in order to retain a modular structure to the tool. This will make development and interpretation of the DST easier, and allow for each component to be upgraded as the individual models are improved.

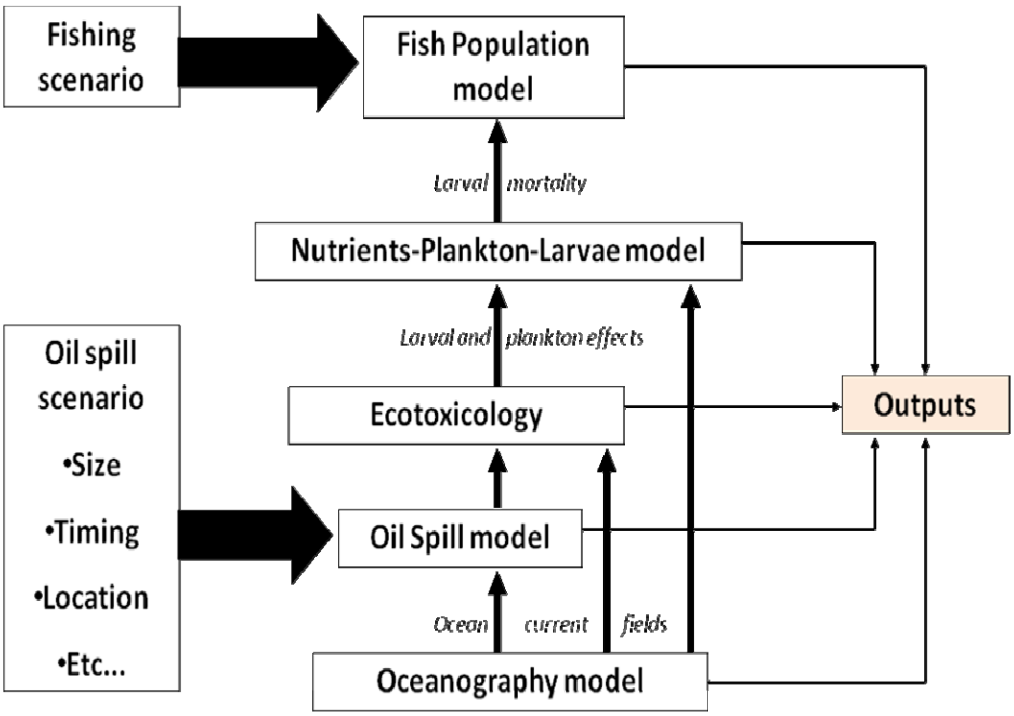

Figure 2. Proposed Decision Support Tool for use in Norwegian oil exploration.

The outputs of the modelling tool will be used by expert groups in preparing their risk assessments. It was considered important that the qualitative uncertainty estimates produced by the modelling be put into context of the wider, often qualitative, uncertainties in the system. Using model results based on a subset of causes of uncertainty is likely to produce an underestimate of the overall uncertainty, which could be misleading if not carefully presented. The tool presented here will enable the production of more accurate risk assessments for the oil industry than is currently possible. In addition the generic framework, and the use of existing ecosystem and fisheries model components, should make it easier to produce comparable risk assessments of different human activities (oil, fishing, etc) affecting the marine ecosystem. This would represent an important step towards an integrated approach to managing the marine ecosystem.

PRONE overview

The PRONE project (Precautionary risk methodology in fisheries) was an EU-funded research project whose main aim was to improve the Assessment, Management and Communication of risk in fisheries management and to provide an integrated approach including biological, economic and social objectives. PRONE did this both by both developing new methodology and by applying reviewing approaches taken elsewhere and showing how they could be adapted for use in a European fisheries context. The work of PRONE related to risk identification, assessment, management and communication. The SG recognized the importance of the work of PRONE and the many important steps it has taken towards developing and implementing a risk framework for fisheries.

Reviews of the risk methodology in other fields made it obvious, that fisheries should adapt methodological approaches from other scientific fields. Especially in regard of an EAFM, and particularly, as there is a longer history in utilizing models for the stakeholder communication. For example the implementation of EU Marine strategy and Water Framework Directive asks for methods applicable to stakeholder communication, and fisheries could be linked to these activities (see Section 6.4, JAKFISH).

Risk Identification

PRONE also compiled a risk register and showed that this could be a helpful approach in cases where there is a need to evaluate which risks are of concern to various stakeholders, and whether the current data collection programs and assessment models can describe the main risks. Especially, in many cases it may be possible to link, with reasonable work load, the current assessment models to some risks having a high status among stakeholders. This would improve the relevancy of the scientific models. There were surprisingly large differences between the stakeholders and even between the fisher's groups, in the same countries, which partly explains why some management issues have been difficult to solve when there are several user groups.

Using a social science approach, which assumed that risk is a subjective concept being a composite of a variety of subjective influences, values and expectations of future events, showed that the actual fisheries management systems has an influence on risk perceptions among fishermen. The study of four contrasting fishery case studies with differing fisheries management systems (UK North Sea, Iceland and Faroese cod fisheries and the Greek hake and prawn fishery) showed that there was a divergence in risk perceptions between inshore and offshore fishermen and across the fisheries. The main findings are that fisheries management systems which utilize individually allocated tradable catch quotas and binding global Total Allowable Catches (TAC) appear to create enhanced risk perceptions in respect of policy, management and control issues. However, systems which utilize individually allocated tradable effort quotas with no binding TACs appear to focus risk perceptions more towards the health of fish resources and the marine environment and away from risks related to economic issues. Fishermen operating under a system which encompasses neither TACs nor any form of individually allocated catch or effort quota appear to be subject to perceptions which cover a wider range of risk issues.

The need to have a simple and transparent way to classify stocks and their limits to controllable exploitation, and hence improve our ability within management activities by providing a general risk identification protocol so that bodies like as STECF and ICES could use such a classification in their documentation (D14). Within theoretical ecology, population dynamics have been classified into colours: red (vulnerable, high risk species) and blue (stable, low risk species) and this approach will be applied to fisheries in order to classify the manageability (i.e. controllability) of those fisheries. The first steps to develop a classification system were taken in D14. System would help to focus the discussion on risk factors dependent on management (poor control), on assessment (poor information) and on specific biological features of the stock. However, more work is needed, especially to include the hierarchical S/R models to the estimation.

Risk Assessment

SGRAMA made many recommendations related to reference points which PRONE addressed by developing hierarchical stock recruit models, which allow estimates from several stocks to be made at the same time, thereby providing more accurate stock – recruitment parameter estimates compared with the current ICES approach where estimates biological reference points are made on a stock specific basis, using relatively noisy stock – recruitment data. The hierarchical approach will help provide consistent biological reference points for related stocks, of particular importance where large difference in reference points for related stocks can reduce credibility with stakeholders. Such an approach will also assume greater importance in the near future, to help support an Ecosystem Approach to Fisheries Management because for most bycatch species the datasets are much smaller than for target species, and there is an urgent need to apply all possible information, including the published papers, expert views and datasets of close by populations.

PRONE also showed how the Bayesian approach can be used in stock assessment to utilize prior knowledge of model parameters and model structures. The conceptually correct and biologically realistic estimation of uncertainties is crucial when risk adverse decision rules are applied, i.e. for example if the precautionary approach is applied; then TAC is dependent also on the uncertainty about the biomass. Bayesian approach offers the most comprehensive way to model essential uncertainties. Bayesian assessments are also important in correctly modelling the variance - covariance structures of the parameters correctly and to transferring the historical uncertainty correctly to the future.

A value-of-information analysis can be applied when planning data collection programs and ranking research priorities. For example information which can potentially reduce uncertainty can result in a revision of the management decisions for a given level of risk, leading to higher catches or mitigation of by-caught species could be prioritized.

Risk Identification, Assessment, Management and Communication

When a shared resource is harvested, policies and tools helping countries to collaborate via international agreements should be sought for and developed. The argument is that all fishing countries will be better off by cooperating, i.e. by complying with an agreement, than by non-cooperating. Harvest control rules can be used as such a tool, provided that HCR is bioeconomically rational. Reference points such as spawning-stock biomass and fishing mortality rate ceiling are commonly applied in the context of precautionary approach. These references can also be used as strategic bio-economic reference points which optimize a harvest control rule. Applying precautionary approach by the grand coalition through a harvest control rule can add net present value of the fishery compared to the case without the HCR. However, the coalition structure and fishing costs have a strong impact on the optimal fishing strategies of the countries. An optimal HCR has potential of stabilizing multilateral fishing agreements if fishing costs are, on the relative scale applied in the case study, high.

Gaps in the knowledge of economic performance of fishing fleets have strategic implications and therefore potential information gaps should be screened for. These strategic implications can be positive or negative depending on whether a country possesses or does not possess economic information, and whether this information is asymmetric or asymmetric and uncertain. Asymmetric information creates problems in a non-cooperative fishery because a country can, by giving false information about fishing costs, manipulate the reaction of the other country not possessing equivalent information about the costs of its adversary. A medium term value of having cost information can be tens of millions Euros in a single fishery.

Another type of a problem develops when a country has biased or uncertain knowledge of own fishing costs. In these situations, management schemes are likely to be suboptimal. Moreover, the probability of excessive fishing pressure is higher of the order of magnitude in the presence of asymmetric and uncertain fishing cost information, compared to case when cost information is asymmetric but not uncertain.

The potential benefits of alternative management systems were also explored for example insurance 9 is potentially a promising tool for the management of large-scale fisheries. It seems obvious, that the current self insurance system of the fishermen is to fish more, even if the uncertainty about the future development of the stocks are brought up. Regardless of whether an insurance system would have positive impact on the behaviour of the fleets. The paper also explored how the fund exposure may be reduced by the application of reinsurance from commercial insurers for the upper tail of high cost - low probability events, such as total fishery collapse.

Risk Communication

"Trust" in fisheries science, a key corollary of risk communication, was evaluated in surveys undertaken in Iceland, Greece, Spain, UK and Faroe Islands. Findings reveal differing levels of trust and mistrust in the fisheries science community between countries and between stakeholder groups, demonstrating areas for future attention in the interests of improving fisheries science and management. Sustainable fisheries management is contingent on the cooperation and participation of all stakeholder groups – both in terms of communicating information and knowledge into the science process and responding to and acting on the communications arising from that process. This work showed that unfortunately, the 'trust' necessary for this cooperation and participation is currently somewhat lacking in current fisheries science.

PRONE: Precautionary risk methodology in fisheries Sixth Framework Programme Priority [Policies 1-3, Policy orientated research (SSP) Contract No. 022589]

Plant health risk appendix

Score	Description	Definition over 5 years: "Chance of occurrence"	Likelihood/yr equivalent
0	**Very unlikely**	**<10%**	0.010
1	**Unlikely**	**10-33%**	0.050
2	**Possible; "as likely as not"**	**33-67%**	0.130
3	**Likely**	**67-90%**	0.270
4	**Very likely**	**>90%**	0.450

Figure 1. Great Britain Non-native Species Secretariat scoring scales for likelihood of invasive species risks. Scores are based on values in the scale used by the IPPC (2005).

Score	Description	Monetary loss, costs	Health impact	Environmental impact	Social impact
1	**Minimal**	Up to £10k /yr	Local, mild, short-term, reversible effects to individuals	Local, short-term population loss, no significant ecosystem effect	No social disruption
2	**Minor**	£10k-£100k /yr	Mild short-term reversible effects to identifiable groups, localised	Some ecosystem impact, reversible changes, localised	Significant concern expressed at local level
3	**Moderate**	£100k-£1m /yr	Minor irreversible effects and/or larger numbers covered by reversible effects, localised	Measurable long-term damage to populations and ecosystem, but little spread, no extinction	Temporary changes to normal activities at local level
4	**Major**	£1m-£10m /yr	Significant irreversible effects locally or reversible effects over large area	Long-term irreversible ecosystem change, spreading beyond local area	Some permanent change of activity locally, concern over wider area
5	**Massive**	£10m + /yr	Widespread, severe, long-term, irreversible health effects	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Long-term social change, significant loss of employment, migration from area

Figure 2. Great Britain Non-native Species Secretariat scoring scales for magnitude of invasive species risks.

***Very High** confidence:*	*At least 9 out of 10 chance of being correct*
***High** confidence:*	*About 8 out of 10 chance*
***Medium** confidence:*	*About 5 out of 10 chance*
***Low** confidence:*	*About 2 out of 10 chance*

Figure 3. Great Britain Non-native Species Secretariat scoring scales for confidence of invasive species risk scores. Scores are based on values in the scale used by the IPPC (2005).

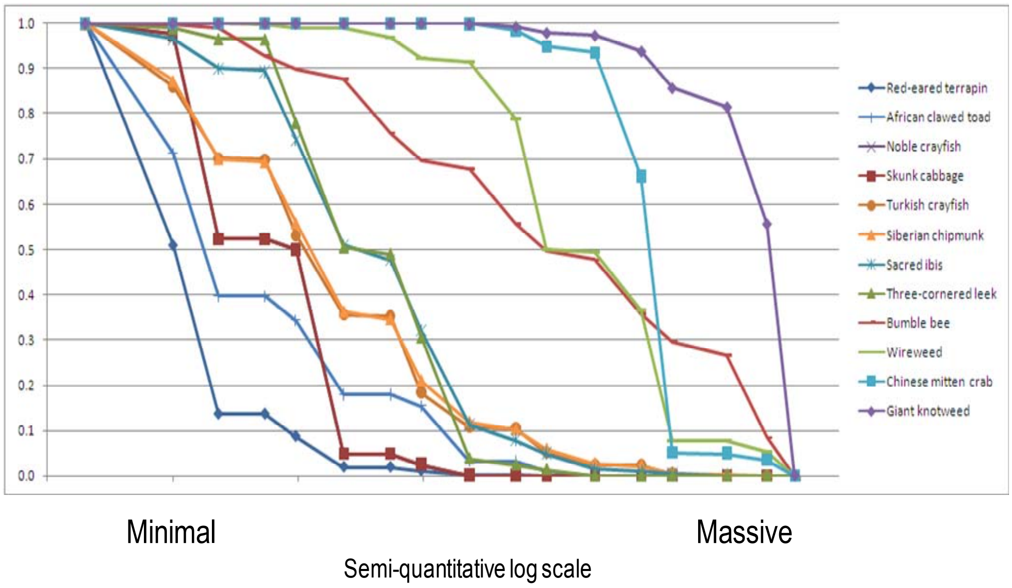

Figure 4. Comparative risk profiles for 12 species assessed by the NNSS in Great Britain.

Fisheries insurance

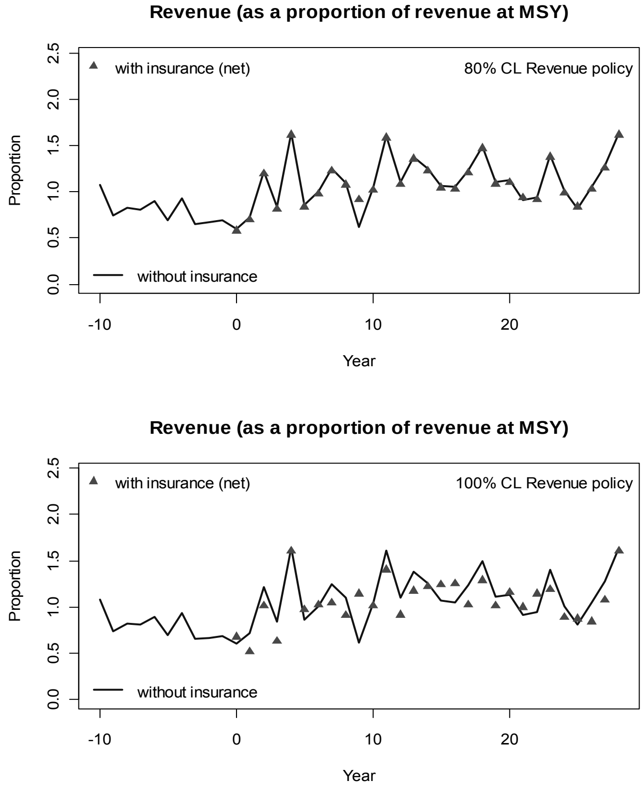

Figure 1. An example of how insurance works in one run of a stochastic model (insurance, no effort increase on falling revenue) at two revenue coverage levels (CL), 80% and 100% CL, where insurance mitigates losses during unexpectedly bad year(s) (see year 9). The relatively high net revenue with 80% cover reflects the low premium for such reduced cover. (From Mumford *et al.*, 2009)

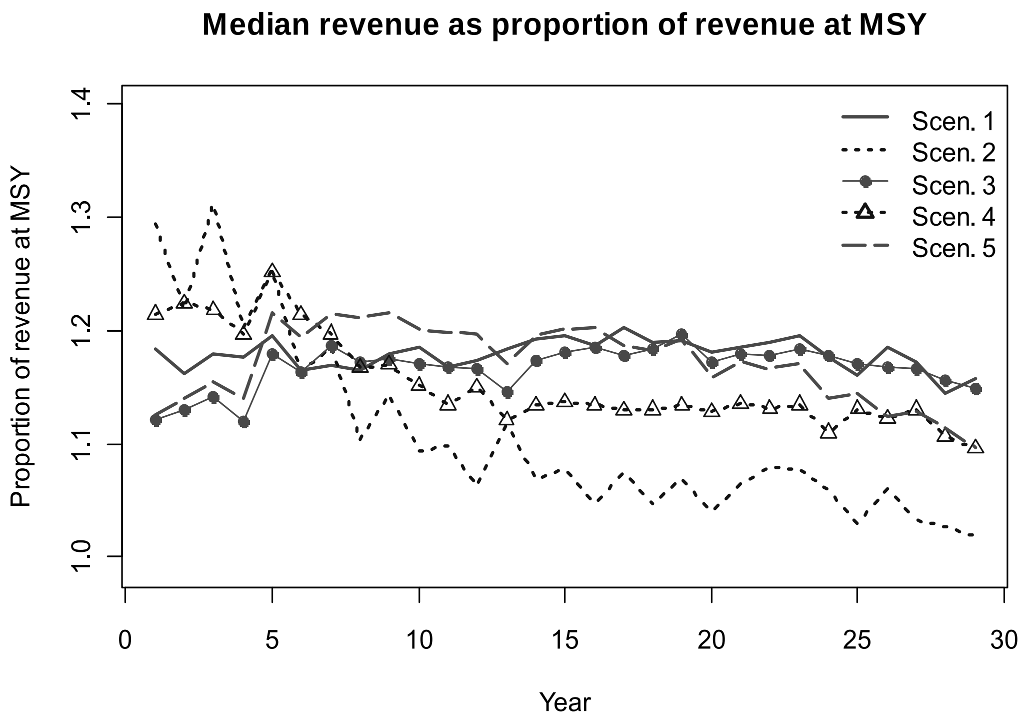

Figure 2. Median revenues for five modelled scenarios: 1) No insurance, no effort increase on falling revenue; 2) No insurance, effort increase on falling revenue; 3) Insurance, no effort increase on falling revenue; 4) Insurance, effort increase on falling revenue; 5) Insurance, 1% annual increase in fishing mortality. There is 100% coverage for Scenarios 3, 4, and 5; maximum effort increase = 1.7 for Scenarios 2 and 4. The process errors are lognormally distributed so the median MSY values are slightly higher than the MSY calculated under-deterministic conditions. (From Mumford *et al.*, 2009).

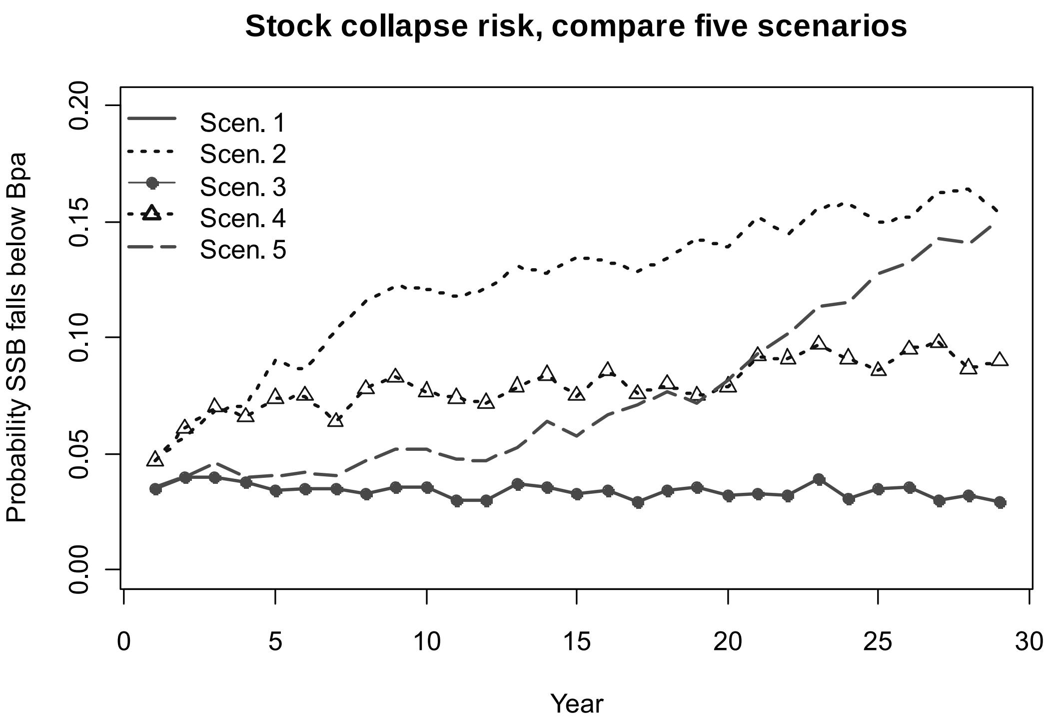

Figure 3. Probability of stock collapse risk, that spawning-stock biomass (SSB) falls below B_{pa} (precautionary level to reliably maintain stock) in a particular year under the five scenarios: 1) No insurance, no effort increase on falling revenue; 2) No insurance, effort increase on falling revenue; 3) Insurance, no effort increase on falling revenue; 4) Insurance, effort increase on falling revenue; 5) Insurance, 1% annual increase in fishing mortality. There is 100% coverage level in Scenarios 3, 4, and 5; maximum effort increase =1.7 for Scenarios 2 and 4. (From Mumford *et al.*, 2009)

Annex 3: Recommendations for the future

The Study Group on Risk Assessment and Management Advice has one recommendation with some considerations listed:

RECOMMENDATION		FOR FOLLOW UP BY:
SGRAMA recommends that further progress within the field of risk assessment as a basis for management advice should be done as a planned case study with a detailed evaluation leading up to a decision whether operational risk assessments should form a basis for advice to fishery managers. The following considerations are listed in support of the ICES internal decision process:		ACOM
a)	A risk assessment is aimed at comparing and ranking possible harmful events and can therefore be used as a tool for prioritising the implementation of an ecosystem approach in the advisory process. The likelihood/probability of harmful events as a result of fishing with their corresponding consequences is not trivial to determine, and comparing quantified risks with qualitative expert judgments is a significant challenge. A qualitative or quantitative risk assessment can form a basis for prioritizing research issues.	ACOM/SCICOM
b)	Experience gained outside ICES points to stakeholder and manager participation as being essential in a risk assessment process. The "how to" part of such participation should be based on recommendations from Working Group on Fishery Systems (WGFS).	WGFS
c)	Risk communication (a two way process involving stakeholders) and the formulation of advice are essential in making risk assessments an operational advisory tool.	ACOM
d)	Risk assessments are a structured approach to identify and prioritise issues. Risk assessment will include inter-disciplinary collaboration on a case specific basis and cannot form a part of long established stock assessment working groups. Experience gained elsewhere points to a workload somewhat larger than was anticipated, but such assessments offered longer term efficiencies if they resulted in effective prioritisation of alternative actions.	All
e)	A risk assessment case study is a "learning by doing" exercise. The case study should be chosen according to the following criteria: • A definable scope to the assessment based on policy objectives • A limited geographical area (ecosystem) with relatively good information on fishing activity being available. • Available managers and stakeholders well motivated for participation. • Available inter-disciplinary scientific expertise including some knowledge of the current fish stock assessments and advice.	ACOM
f)	The planning of, and conducting of a proper evaluation of the case study is needed. In particular, criteria for the success (or failure) of the risk assessment need to be defined upfront.	WGFS